ON MENTAL BIOLOGY

FIRST PAPER

5.

THE CAUSE OF SLEEP

BY

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ON MENTAL BIOLOGY, FIRST PAPER.

THE CAUSE OF SLEEP.

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INTRODUCTION. H. C. Stevens of Ithaca says that when one compares Lehmann's extravagant claim with the actual state of the psychology of the feelings, one cannot but wonder at his temerity. Shields, Binet and Henri, Binet and Courtier, Angell and Thompson, and Bonser found negative results. Kulpe found contradictory results as regards the rate of pulse in unpleasantness, and Gent as regards rate of pulse in pleasantness; Zoneff and Meumann alone find an opposition; Binet and Henri and Binet and Courtier find no differentiation. Other observers have either found vasoconstriction for all stimuli, or they deny any kind of correlation (Am. J. of Psychol., Vol. 16). Ellis and Shipe of Austin say: "The results force upon us the conclusion that the methods of studying fatigue are worthless. When we surrender our present vain knowledge, and come to the problem fresh and unbiassed is there hope of solving it" (Am. J. of Psychol., Vol. 14). Buchner of Tuscaloosa suggests that the worth of the results of psychological experiment has not been commensurate with the great ingenuity and assiduity displayed (Psychol. Review V). Thinking perhaps of the carefully prepared conditions which cut out all natural relations, or of the usual one-sided work in sensation alone, Prof. Billia of Turin said: "In spite of all its good intentions, the psychological laboratory destroys psychology and also ethics" (3 rd Int. Cong. of Philos., Heidelberg). There appears also to be no physiology of normal man studied in physiological laboratories. Animals under the influence of curare, ether, chloroform, morphine, nicotine, urethane, vagotomy, vivisection or artificial respiration, give chiefly artefacts. (The English school of physiologists have lately turned their attention to the direct study of the normal human being with brilliant results.) The usual apparatus for recording movements is made partly of India-rubber, the grotesque behavior of which under varying tensions precludes quantitative results (Figs. 4, 5, 6, 12). Long, light, rigid levers seem preferable, as they record motion without distortion. One clear experiment seems preferable to a hundred questionable ones. It is often best to take the apparatus from laboratory to living room and to use as little of it as possible. Often experimentor should appear indifferent: read a book, etc., during experiments. This investigation is based upon no psychological assumptions. The physiological assumptions are that life is supported by oxidation; that the cerebrum is the seat of conscious, volitional activity, and the lower centers of reflex automatic activities; that local increase of CO_2 and decrease of O lessens activity of cortex and stimulates the breathing center; that this center has a specialized sensitiveness for CO_2.

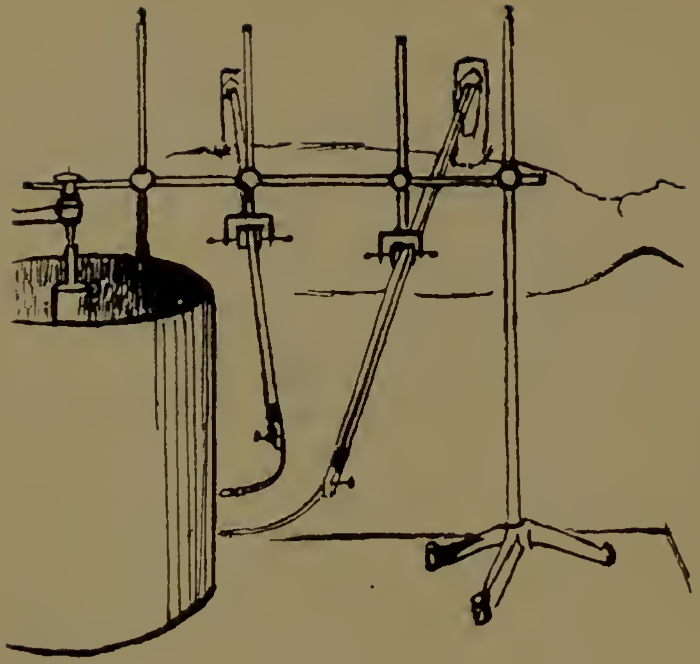


Fig. 1. **Sketch of Lever Pneumograph.** Levers are of wood (walnut). To prevont interference of levers writing points are on approximate sides of levers and differently bent. The points are mounted on sliding brass collars. A third lever for waist is also provided. The recording drum used has a circumference of 50 cm and revolves in 2 to 6 minutes, as adjusted. Length of levers 1 meter. (Hollow aluminum rods preferred.)

All curves read from left to right.

Down stroke, inspiration; up stroke expiration.

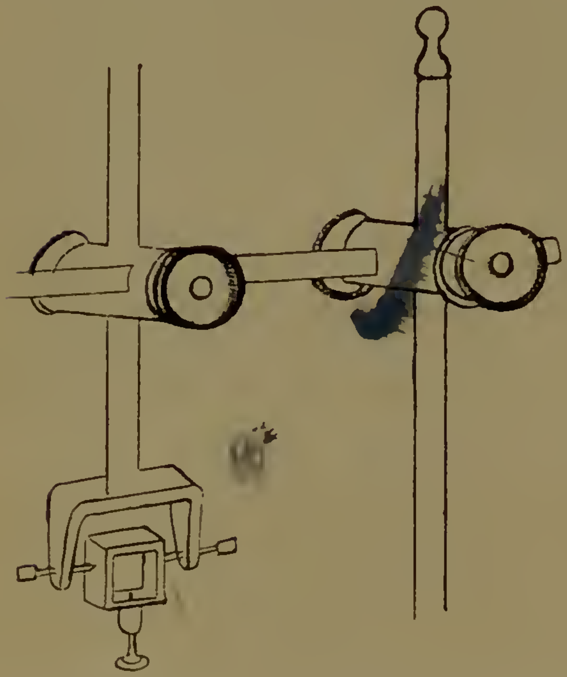


Fig. 2. **Pivot and Portion of Support for Lever.** By adjusting the pivot at various points on scale of lever, any desired ratio for magnifying or minifying record of motion may be obtained. A movable counterpoise with binding screw is used on shorter arm.

For figure of circummeter (to record on one drum exact changes of circumference in several planes) see next paper.

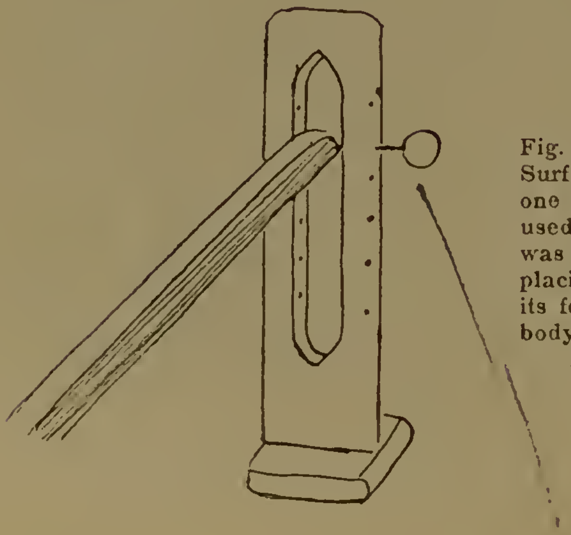


Fig. 3. **The Antenna** for taking the movement. Surface for contact should not be larger than one inch square. American chewing-gum was used for attaching it to skin when subject was sitting. In sleep experiments merely placing the counterpoise near antenna insures its following the downward movements of the body wall. Author's instrument maker is E. Zimmermann (Leipzig and Berlin).

The purpose is to treat of mental biology. The biology of the mental processes or functional psychology will be treated through the medium of human and comparative physiology and natural history. Short experimental papers will be published on Sleep, Consciousness, Desire, Moods, Feeling, Emotions, Motives, Mental Attitudes, Mental Hygiene, etc. To introduce the biology of mind, no subject seems more promising than the process of going into the state called sleep and awakening therefrom. The change is so marked and distinct that we have obviously to hope for more salient features to study than we would find by beginning the attack through study of the more slightly varying moods and changes of the waking state. Respiration will be studied for this is the only function which alternates quickly and constantly between voluntary and involuntary action. It closely yokes the slow chemical changes and the quick acting nervous system. This system was evolved for quick adaptations to environment without superseding the chemical relations which existed before a nervous system came into being.

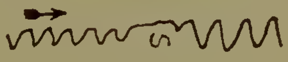


Fig. 13.

Fig. 13 shows portion of a respiratory curve taken while a subject went to sleep with antenna of lever resting on sternum between the ends of the sixth ribs. The fifth breath shown (400th. breath in curve) is shallow, then follows a pause in passive position or what may be called the rest line (after expiration) of about 8 seconds. [The breathing is at the rate of about 15 breaths per minute, or one in 4 seconds, and since this pause equals two breaths, it must be 8 seconds in length.] The first breath after the pause is very shallow, and then the breaths become deep, regular, and slower, the outward motion of chest wall (at the point recorded) being now just twice as great as when awake. Fig. 14 a curve taken from the same subject on another night, shows almost the same changes in the movements of the chest wall. Here, however,

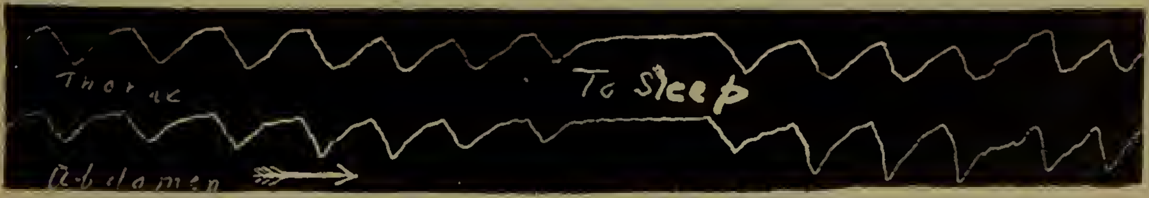


Fig. 14. To sleep without previous dozing. Respirations become deeper. Rate unchanged. Long pause preceded by shallow breath as in Fig. 13. (W. M. C.)

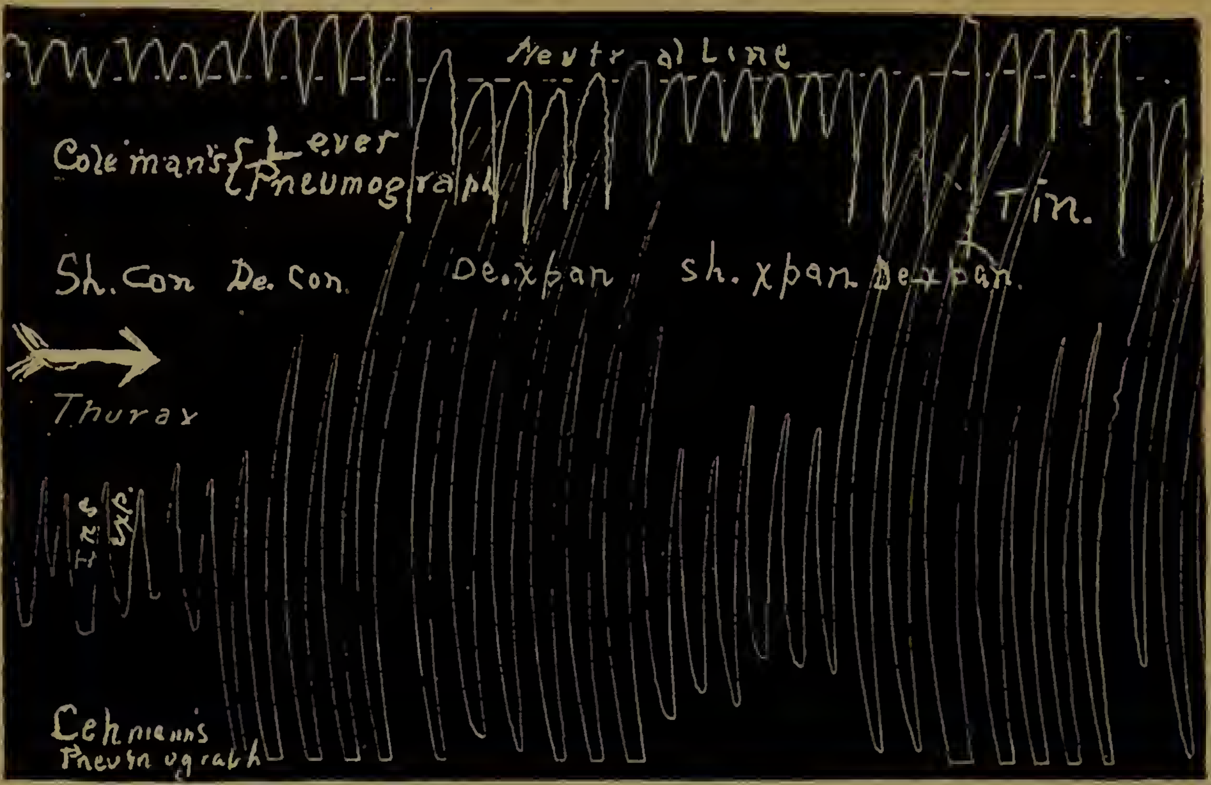


Fig. 4. **Comparison of Curves** written by Lever (above) and Rubber Pneumograph with Marey's Tambour (below). Antenna and bulb on homologous points of chest. Lower curve should be straight where it is curved because of short lever in tambour. It should be curved where it is straight (at turns). It magnifies the real movement more when tension is slight, and less when tension is great.

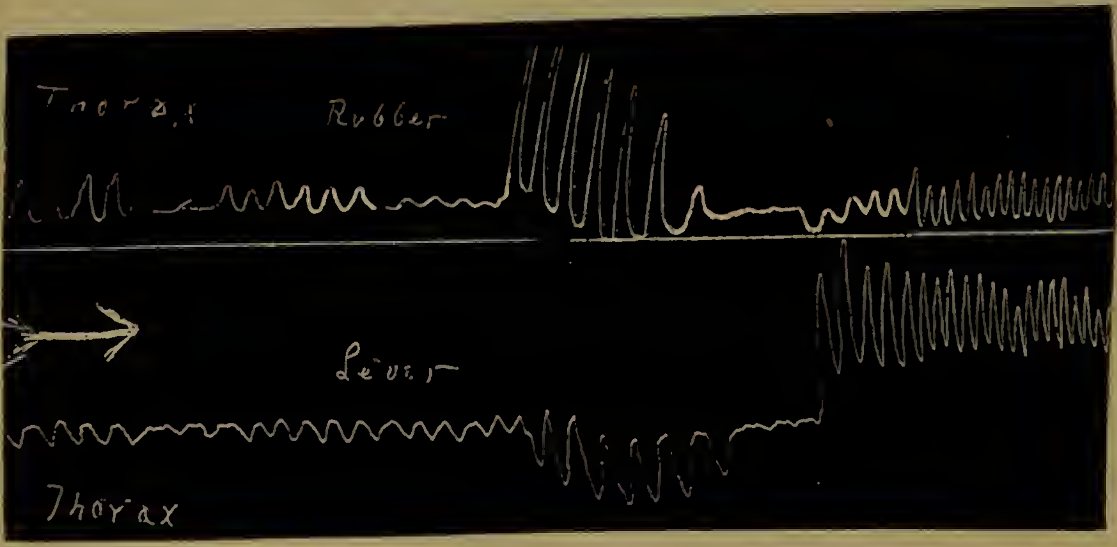


Fig. 5. Showing falsification of bulb and tambour in opposite senses (compare with lever).

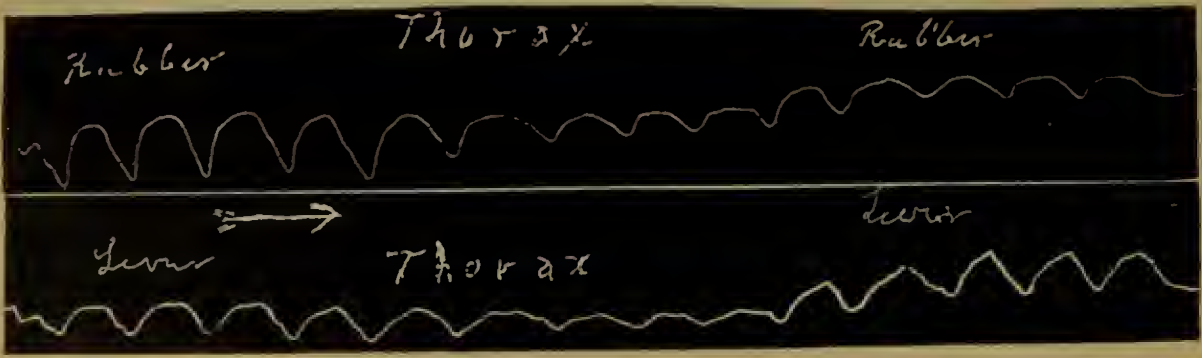


Fig. 6. Behavior of rubber under slight changes of high tension. For true curve, see lever.

the movements of the abdominal wall below waist line are also recorded by a twin lever. These movements almost parallel those of the chest, and the movements of the abdomen increase in depth after the pause of about 10 seconds which ushers in sleep.

It is important to determine as nearly as possible the moment at which consciousness disintegrates. This determination was attempted by having subject hold a cord which passed over a pulley and sustained a weight, and again by having subject hold up hand or finger, but the weight and the hand always dropped before sleep came. The most satisfactory method was for experimenter to listen with ear close to subject, and note (by marking on record) the first slight puffing sound heard by the breath striking nostrils, as it does as soon as subject relaxes and "falls" asleep or within a few breaths. Such sounds are marked in Figures 12, 20 and 21.

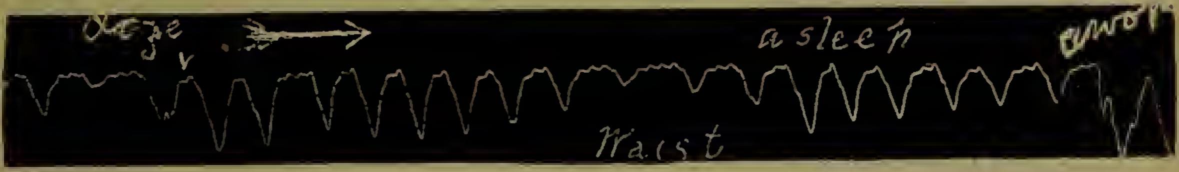


Fig. 15. Doze, awake asleep, awake. Pulse is distinct because antenna is on waist.

Another method was to instruct a sleepy subject to raise a finger or to speak a syllable as soon as he returned to consciousness while dozing. Such moments of dozing are shown in fig. 11 and prove that the mind may become completely lost in a dream during one shallow breath or in about four seconds. We find a similar result if the experimenter speaks to the subject at the end of the pause, — the subject reports himself as dreaming (Fig. 16).

The mental state during apnoea (as tested by Whipple) favors passing into a state of unconsciousness, viz: dizziness, mental confusion, lengthened reaction time, decreased memory span, longer discrimination time (Am. J. of Psychol., Vol. 9). The effects are doubtless due to suspended expiration impeding blood flow through brain.

A study of the various curves will soon suggest several questions: Why is the onset of sleep usually accompanied by a respiratory break or pause? (Figs. 8, 12, 13, 14, 15, 18, 19, 20, 21, 23.) What causes the pause? Why is a short pause (Figs. 11, 12, 15, 16, 19, 23) followed by dozing, and a longer pause followed by sleep? Why is breathing usually deeper (Figs. 13, 14) or faster (Figs. 21, 22) when sleep begins than during waking? What causes

Fig. 7. Effects on position of thoracic wall of several forms of breathing. Position of passive wall varied 7 mm. Such an experiment is impossible with rubber apparatus.

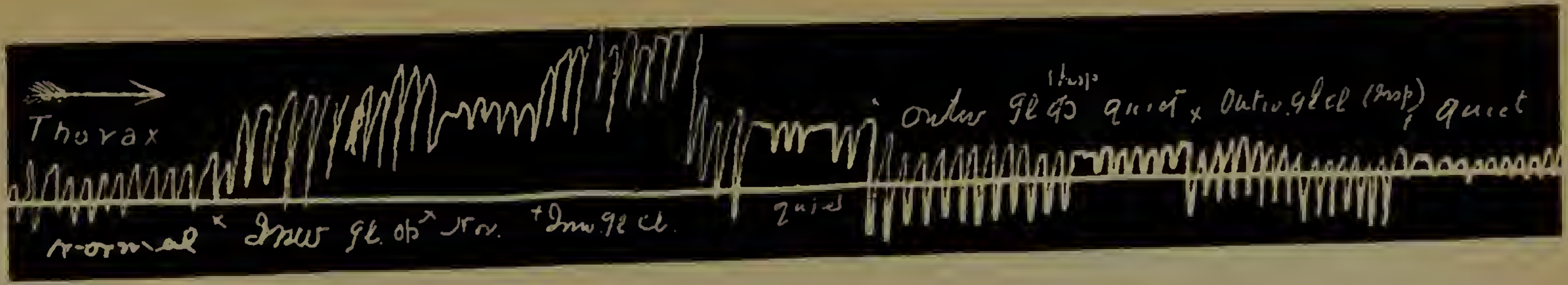


Fig. 8. Respiratory record taken when lever was not level. A child of nine. Marks show "awake", "spoke", "slept".

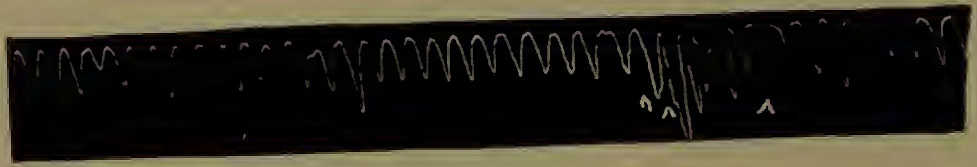
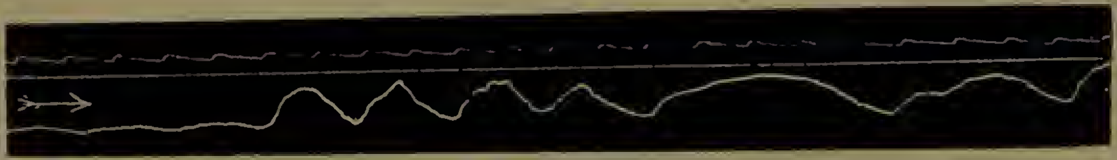


Fig. 9. Pneumograph lever and Frey's Sphygmograph used together.



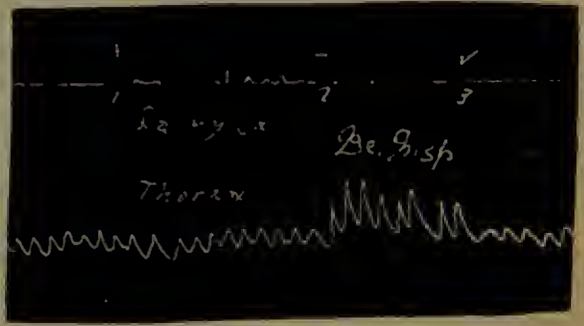


Fig. 10. Author's Laryngograph and Pneumograph used together.

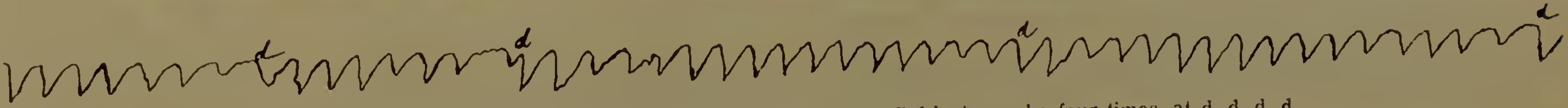


Fig. 11. Four dozings (d) — traced from kymograph curve. Subject a woke four times, at d, d, d, d.

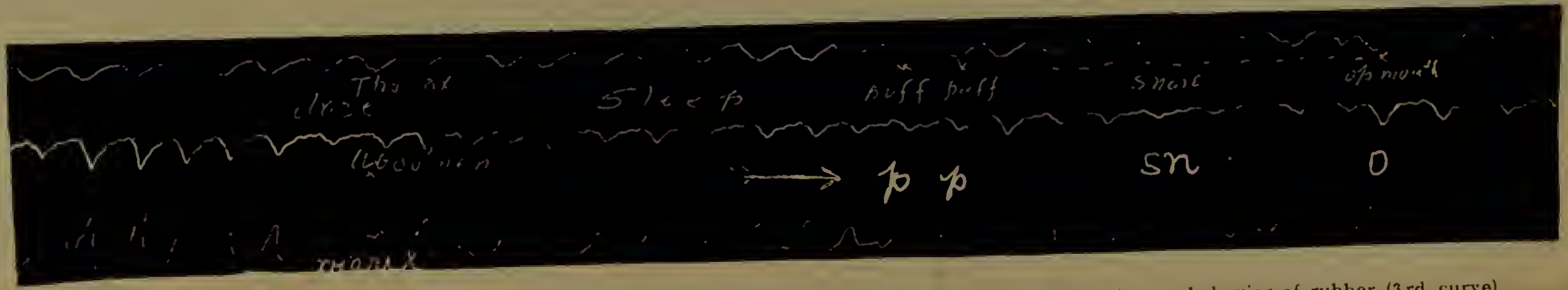


Fig. 12. Dozing, Sleeping, Snoring. Mouth opened at x. Curve from rubber pneumograph shows grotesque behavior of rubber (3rd curve).

the wavelike variations in depth seen in some of the curves? (Figs. 8, 11, 12, 15, 16.)

The basal doctrine of modern biology is that the life processes, including the activity of the brain, are sustained by oxidation. Slow or shallow breathing by lessening of ventilation and slowing of blood flow, allows diminution of O and increase of CO_2 to occur. Holding the breath retards the circulation still more. We know this for Hill and Flack (J. of Physiol., vol. 37) found that breathing freely in and out of a small closed space containing impure air extends the power to withstand excess of CO_2 and want of oxygen.

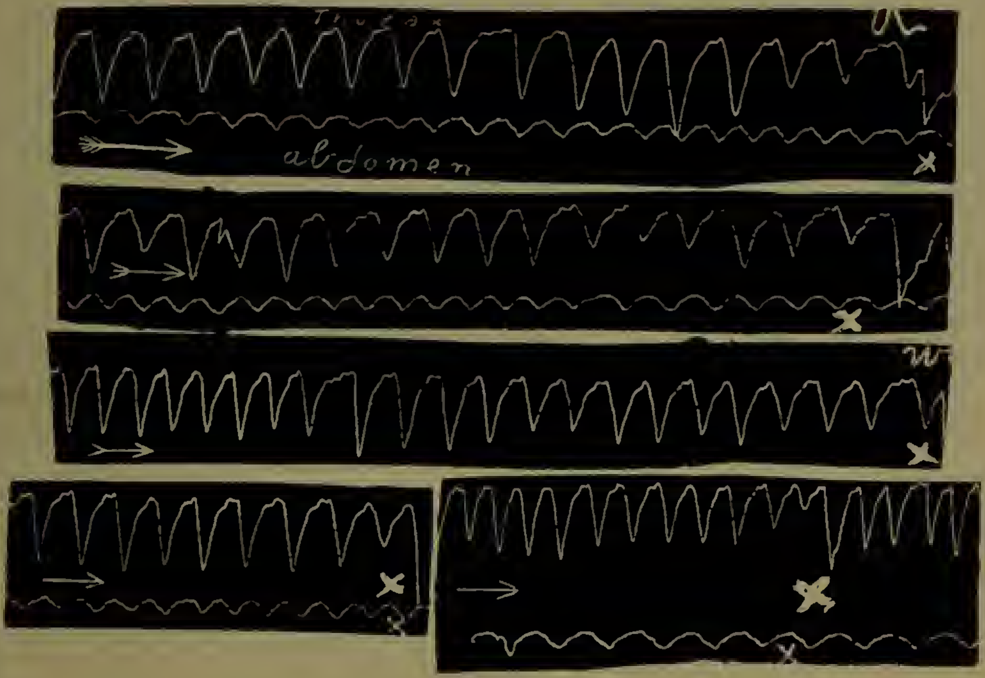


Fig. 16. Five dozes at x. One or two shallow breaths at each doze. Compare with Fig. 11.

This is because the circulation is not mechanically impeded as it is when the breath is held, for then the blood containing oxygen in the outlying parts of the body is circulated less freely to the coronary arteries and to the brain; at the same time the CO_2 can not be so rapidly removed from the tissues by the less efficient circulation. Lewis found (J. of Physiol., vol. 37) that suspended thoracic expiration (Figs. 13, 14) produces fall of blood pressure.

We thus see that a respiratory break or pause causes the O-want or CO_2-excess in brain. The effect on cortex brings about mind-wandering and loss of consciousness. The effect on the breathing center (which is highly sensitive to CO_2) is the deep or more rapid breathing which usually follows the pause preceding dozing (Figs. 11, 15, 16, 19) or sleep (Figs. 13, 14, 15, 19). The method of reading from the curve whether CO_2-excess alone, or this combined with O-want, is present in the brain will be given later. As to whether the respiratory pause resulting from the cessation of cerebral impulses will terminate in a doze and return to consciousness or be prolonged and bring sleep, depends upon the state of carbonization of the tissues and blood. If the tissues are not already too much carbonized from fatigue or other causes, the resumption of full breathing and the consequent improvement in the circulation may so oxygenize and decarbonize the cerebrum as to restore the cells to a condition of work. If the tissues were already highly carbonized, this will not occur, but the brain vessels will dilate (see later) and the slow blood will add to CO_2-excess and deepen the sleep.

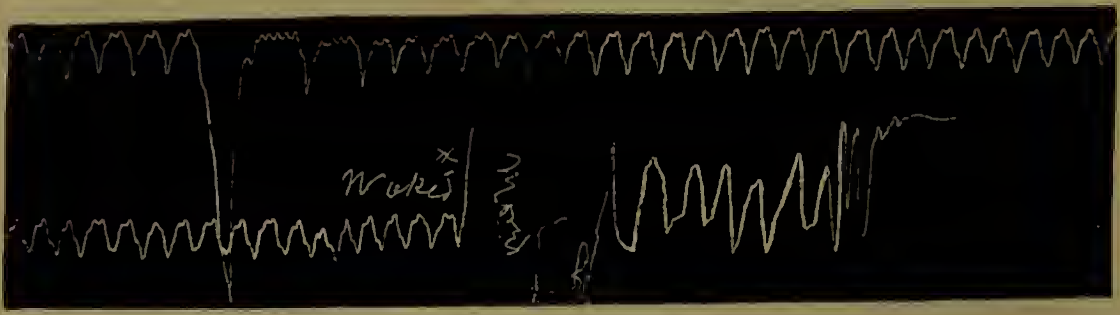


Fig. 17. **A Sigh** followed after a few breaths by sleep. Antenna on waist. (L. L.)

But what causes the respiratory pause in the first place? The cessation of all cerebral impulses to the breathing muscles is usually preceded by a short period of marked excessive breathing. This so ventilates the lungs and oxygenates and decarbonizes both brain and medulla that both cease to send impulses to the muscles of respiration and a condition of apnoea ensues. Fig. 17 shows a sigh soon after which the subject slept. Fig. 21 shows a slight sigh followed by three voluntary breaths, then by two shallow breaths which brought sleep and left the subject with the chest expanded. If the reader will apply a straight edge to this record he will see that the rest line has moved out 1.5 mm. Fig. 18 shows a sigh followed by more complete apnoea than in the other cases, but the sigh was drawn in such a way that the action of the heart was increased, for as the record plainly shows the pulse is very strong during the apnoea. This oxygenated and decarbonized the nerve cells, hence this sigh was not followed immediately by sleep. Sleep occurred in the portion of fourth curve shown (each curve being 50 cm long) during the shallow breaths towards end of curve. The difference between a spontaneous sigh and a purely voluntary one and their effects will be discussed in a later paper. The act of lying down, the relaxation of muscles (except respiratory muscles), the diminution of sensory impressions all tend to apnoea. Such changes may so prepare for sleep that no preliminary surplus breathing (as breathing beyond the needs of the organism may be called) and no decided break, occur on going to sleep. (See Fig. 22.) Author has evidence that the breathing may sometimes become otherwise involuntary before muscles of larynx and eyeballs relax.

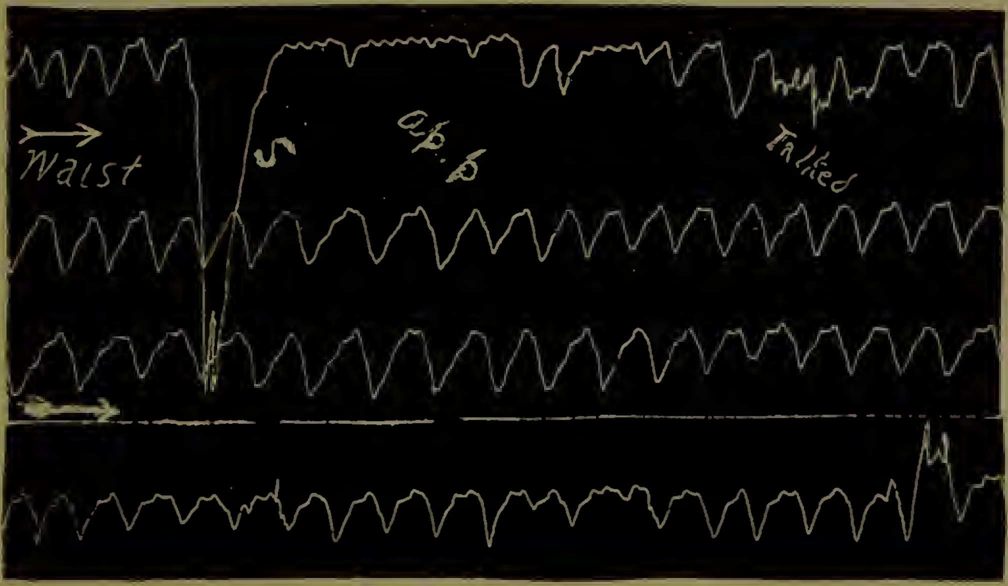


Fig. 18. **A Sigh**, s, followed by apnoea. Subject went to sleep in fourth curve with one shallow, one nearly full, and one shallow breath. (A. M.)

The important part played by changes in glottis in going to sleep will be shown in the paper on Consciousness. The papers are experimental and this cannot be discussed here because no clear records are at hand, author's laryngograph being still unsatisfactory (Fig. 10). Although this paper is based on unnumbered hours of experiment and observation on normal human beings, certain physiologists will say that it is not experimental, because experiments are not on curarized cats and etherized dogs.

Surplus breathing is necessary under most varied conditions; only thus can the cerebrum relieve itself of the tyranny of the reflex

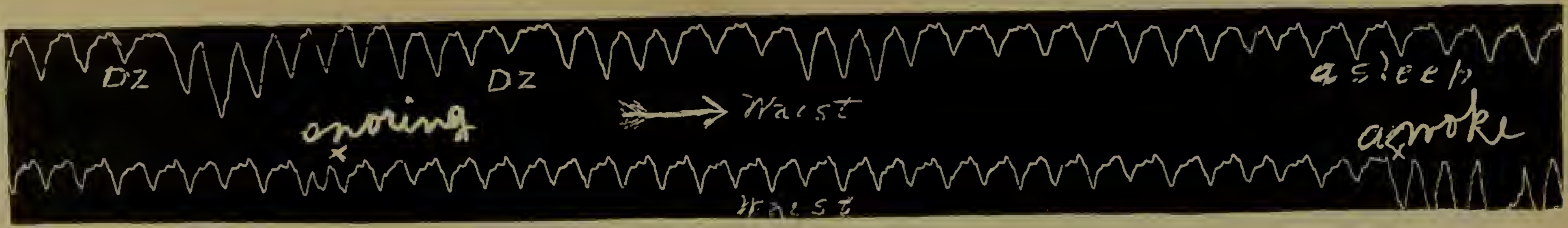


Fig. 19. **Dreamless Sleep.** Two dozes, slept, two snores, awoke. 56 (perfectly regular) breaths are omitted between first and second curves. Breaths while sleeping are of almost absolutely even height, with heart beats homologous in each wave. Even after two snores wave resumed its characteristic form at once. (W. M. C.)

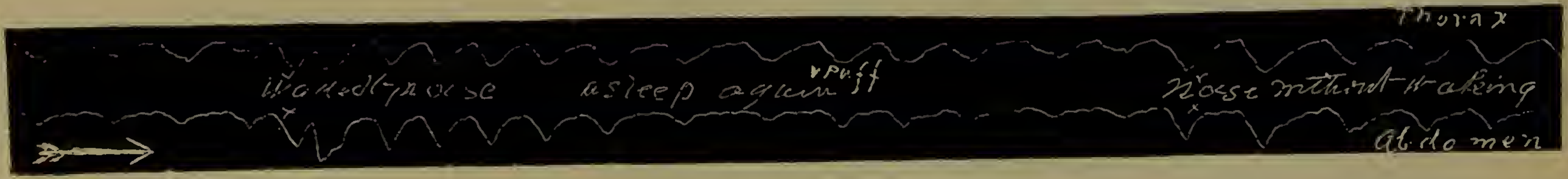


Fig 20. Movements of abdomen and thorax closely similar. "Puff" indicates where breath became purely automatic and jerky. Jaw fell slightly at this point. (W. M. C.)

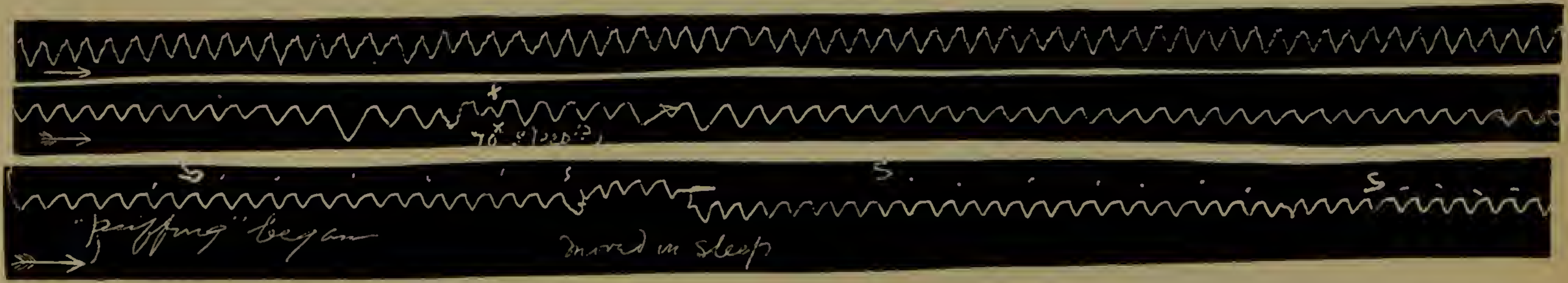


Fig. 21. First curve taken from front of waist, and shows pulse. Subject, not sleeping, changed position and antenna was placed on side of waist (second and third curves, which are continuous). Puffing began 48 breaths after point where sleep probably began. (C. R. M.)

centers. This becomes indispensable during voluntary muscular acts involving the trunk and arms, for involuntary breathing at critical moments would render accurate control of the muscles impossible. Monkeys make great use of the arms, and author has observed that their breathing is largely abdominal in consequence. Flying requires nice muscular adjustments and birds have air sacs which render use of lungs unnecessary while in flight.

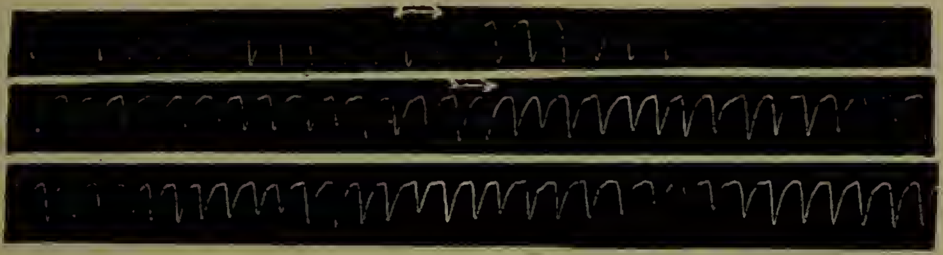


Fig. 22. Subject awake in first curve, and asleep (probably after a short pause not shown) in second and third curves, where periodic variations in depth (Cheyne-Stokes) of breaths are apparent (oxygen-want). (N. N. B.)

That breathing is unconsciously though voluntarily used to regulate the mental states, has already been suggested by author. In "Human Biology" (part of an elementary biology published in conjunction with Prof. Bailey of Cornell Univ.) he says: "Carbon dioxid is nature's narcotic. The drowsy feeling that ensues from it is more pleasant than the drowsy feeling from alcohol or opium. Those who do not employ nature's narcotic but free themselves from its influence by hurried, anxious breathing, become restless and crave artificial stimulants." See also author's Hygienic Physiology ninth reprint, page 206. Hill and Flack found that a hot bath doubled the time that the breath could be held (J. of. Physiol., vol. 38). The above facts are not in conflict with Haldane and Priestley's discovery of the sensitiveness of the respiratory center to changes in carbon dioxid in a quiet, inactive, unemotional state. Even in this state the alveolar CO_2 of one subject tested varied from 6.83 percent to 5.90; in the other subject, from 5.87 to 5.40 (J. of Physiol., vol. 3). H. Boruttau (Erg. d. Physiol., 1904, II) says that the last supporter of the purely reflex nature of the respiratory movements has taken his views to the grave with himself.

The subjects from whom the curves in figures 12, 19, 20, 21 were taken, breathed under the influence merely of CO_2 in the brain; while the subjects who wrote the curves in Figs. 11, 14, 15, 16, 22 were influenced by both O-want and CO_2-excess. Why is this? Boycott and Haldane (J. of Physiol., vol. 37) and Douglas and Haldane (vol. 38) have shown that increased acidity of blood from lactic and other acids lowers the pressure of CO_2 required to stimulate the breathing center, that the increase of these acids occur when there is O-want, and that when regulation of respiration depends partly upon oxygen, the greater variability of the oxygen supply causes the center to "hunt" like the governor of an engine, in regulating the breathing. Hence the periodic variations in waves shown in Figs. 11, 14, 15, 16 and 23 prove O-want in respiratory center.

One apparent objection to the authors explanation is that the subject usually breathes either faster or deeper after sleep begins, and according to the theory, this should cause waking. Of seven subjects shown in accompanying curves, three (Figs. 8, 13, 18) breathed more deeply when sleep began, and four (Figs. 17, 21, 22, 23) breathed more rapidly. (To avoid error from gradual slowing of kymograph, the breaths were measured directly before and after going to sleep.) This increased breathing, however, only partly compensates for the loss in ventilation of the centers caused by slowing of bloodflow in brain which comes about during the pause. The slowing occurs because (1) the blood vessels are dilated, (2) the arterial pressure, forcing blood into brain, is diminished. That this pressure is diminished is indicated by the following experiment of author: June 20, subject lying down, blood pressure in arm taken with Riva-Rocci sphygmomanometer was 118 cm Hg. at 11.50 A. M. It was 118 at 11.53; it was 118 at 11.58. At 12.01 P. M., the subject being asleep, the blood pressure was 110 cm Hg. At 12.03, the subject being awake, it was 118. At 12.13 it was 117. The subject slept again soon afterwards, but the reading taken then was doubtful. The subject was awakened by some one entering the room, and the mercury rose suddenly to 122 cm. The reading of 110 we know was taken during complete sleep because when subject awoke he did not know that reading had been taken, having been totally unconscious of the pressure of the band on the arm, a pressure that was always acutely disagreeable to him.

Such an experiment cannot be repeated at will, and the method is inexact. Author has not seen another measurement of blood pressure taken 3 minutes before and 2 minutes after dozing. Brush and Fayerwether (Am. J. of Physiol., Vol. V) found an average fall of 9,8 mm Hg upon going to sleep. Observations before and after going to sleep were made $^1/_2$ hour apart. In no case during sleep did the pressure fall so low as in the first observations taken after going to sleep. Hill (J. of Physiol. 1898) found pressure had fallen 5 mm Hg within $1^1/_2$ hours after going to sleep. Wm. Hammond ("Sleep and its Derangements", N. Y. 1869) demonstrated by means of a manometer that the blood pressure in the brain is less during sleep. Wier Mitchell's experiments confirmed this. L. Hill ("Cerebral Circulation", 1896) has shown that a rise in the arterial pressure produces an increased velocity of bloodflow in the brain. A fall of general pressure probably produces a decrease in velocity.

Aulo (Skan. Arch. f. Physiol., Bd. 21) found that during sleep the pulse frequency decreased markedly. Example: pulse $91^1/_2$; during 10 minutes subject went to sleep and pulse sank to 80; remained between $74^1/_2$ to 82 during 15 minutes; awoke, pulse rose to 93.

That there is passive (not active) congestion in the brain is also proven by following facts: Brodmann (J. of Psychol. and Neurol., Bd. 1) and Shepard (Proc. Am. Physiol. Soc., 21st an. meeting) found that the brain increased in volume on going to sleep. The pulse in brain become freer, indicating vaso-dilation. But Shepard says that the change in size of the smaller vessels in the brain may disturb the connections of the axones and dendrites sufficiently to bring on sleep!

The shallow or slow or suspended breathing on going to sleep with its effect on circulation and supply of oxygen and carbondioxid probably causes through the vasomotor system the increase in volume of periphery at the moment of going to sleep, observed by Mosso, Howells and others. This reaction perhaps dates from the time when the skin was an organ of appreciable importance for the respiration. This shallow, slow, or suspended breathing acts through vasomotor centers or otherwise to cause a relaxation of the cortical vessels which, with the general lessening of blood pressure at the moment of going to sleep, brings about a slowing of blood flow in brain. The shifting of blood to surface, the decrease of general blood pressure and relaxation of cortical vessels, all aid the change in respiration to cause slowing of bloodflow and decreased metabolism in cerebrum; thus fixing the condition of lessened cerebral activity of sleep. E. Weber has given a new interpretation to Mosso's experiment of the human balance when the head rose during sleep (Arch. f. Anat. u. Physiol., 1907). He proved that this is not caused by anemia of brain. In another masterly paper he has proved that there is a vasomotor center located brainwards of medulla which dilates cerebral vessels (Arch. f. Anat. u. Physiol., 1908).

That the dilation and stagnation is in cortex (which would throw the cerebral motorcells out of function) is clearly indicated by W. Hunter (J. of Physiol., vol. 26) who found "a dense plexus of nerve fibers surrounding vessels in the substance of the gray matter. On reaching the white matter the vessels lose the fibers entirely."

Intra- and extra-vascular cranial pressures must change in opposite directions when the cortical vessels relax under diminished arterial pressure. Unless the brain shrinks very rapidly from shifting of cerebro-spinal fluid and venous blood, there is a temporary rise of extra-vascular cranial pressure (Shepard, Brodmann) which aids the slower blood supply to increase the CO_2 gas pressure, and thus narcotize the cerebrum but stimulate the medulla.

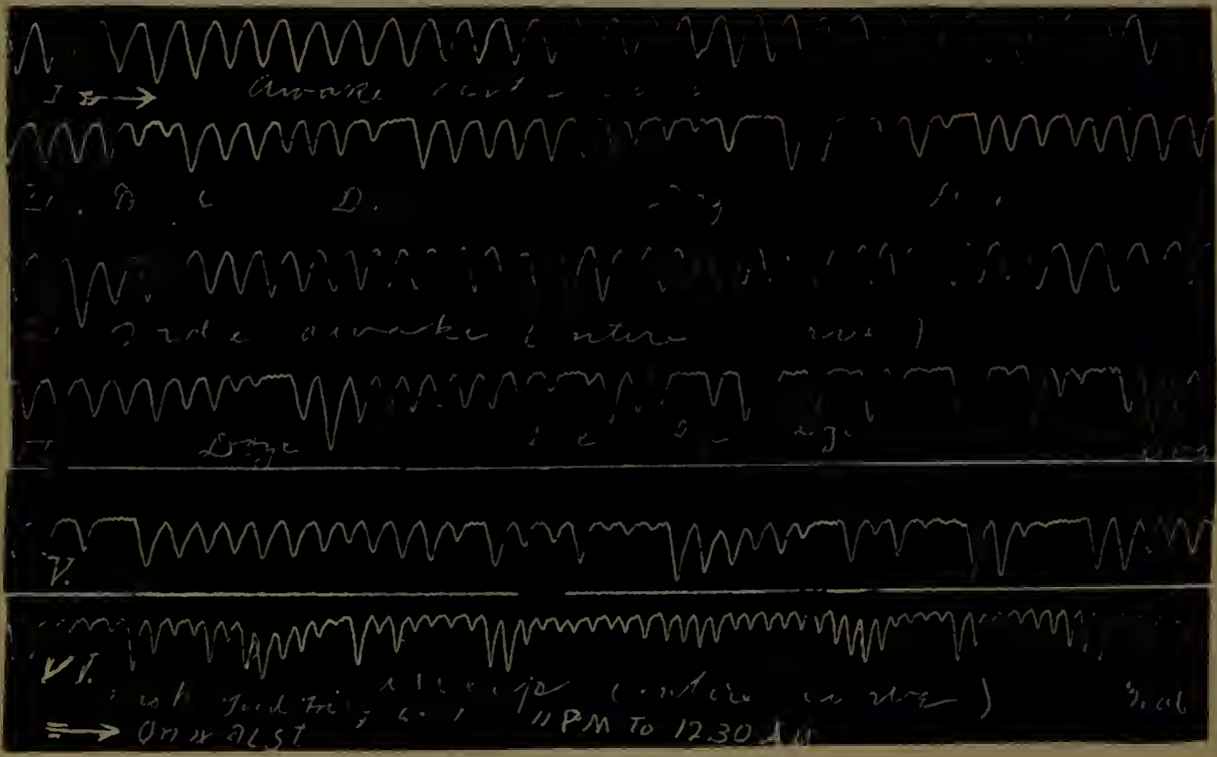


Fig. 23. **Periodic (Cheyne-Stokes) breathing.** I. Awake; II. Four dozes; III. Wide awake; IV. Dozes with waking; V. Goes to sleep; VI. Asleep; waked at end. (E. H. W.)

Excessive Periodic (Cheyne-Stokes) Breathing. Among the subjects experimented upon, one (Miss E. H. W., aged 19) gave curves which show the variation from very shallow to deep breathing while dozing and while going to sleep in the form called Cheyne-Stokes breathing (Fig. 23). This has hitherto been regarded as always pathological phenomenon, but Douglas and Haldane (J. of Physiol., vol. 38) have recently disproved this, and found one cause to be lactic acid and O-want after apnoic pause.

This curve, as well as all curves written by lady subjects, or when the author himself become subject, were taken by his wife, to whose practiced and skilful assistance during the investigations for the last ten years, any serviceable results, if such have been reached, are largely due.

The subject reported after a series of pauses (curve II) that she had been dozing. In the case of a patient of Merkel (quoted by Mosso, Archiv. f. [Anat. u.] Physiol, 1886, Sup. Bd.) who had Cheyne-Stokes breathing for a week, Merkel observed that the patient slept during the intermittence and awoke in the period of respiratory activity. If a question was asked in the beginning of intermittence, he answered after its end, slowly and with trouble. The subject of our experiment went to sleep by the (Cheyne-Stokes) periods becoming and more frequent until finally they appeared as in curve V. At the end of curve VI the outward motion of waist is shown as she awoke spontaneously and talked; no more curve was taken that night. The only disadvantage of the pneumograph levers is that the subject must lie or sit still unless the experimenter is to have the trouble of readjusting writing point to drum after each movement of subject. The thought occurred that perhaps the periodic breathing in this subject was caused by lying still; hence a rubber pneumograph was once substituted, but subject developed same kind of breathing as on previous occasions. She slept longer at this time, however, and the breathing lost its periodic character after about 20 minutes of sleep.

DREAMLESS SLEEP. Figure 19 was written by same subject on same evening as Fig. 14. 5 This subject (the author) had written curves while going to sleep on perhaps twenty different occasions before, both during afternoon naps and at night, but had never written a similar curve; neither had it been observed in his case during experiments with his "mirror pneumograph" (begun in 1899). On this night however, he felt completely relaxed, placid and indifferent, though not tired, and fell asleep promptly several times. Twice when he awoke it was with a slight (inspiratory?) jerk or start and a sensation of falling not *down* but *in* darkness (caused doubtless by the jerk the sense of gravitation being absent) but without any remembrance of having been dreaming: a feeling merely of coming out of complete blackness and vacancy. That he awaked spontaneously at all before morning may have be due to the fact that he was sleeping in the front room of a house on a much used thoroughfare on which noisy automobiles and street cars were frequently passing. Subject dozed once and slept once in portion of curve shown in Fig. 15. He dozed twice (periodic) and slept in first curve of Fig. 19, and continued to sleep through second curve, awaking five breaths before the end of the curve. Fiftysix similar waves are omitted between the portions shown. The breaths are remarkable for being of almost exactly the same height. Another remarkable feature is that there is only one rhythm, that is that the rhythms of the heart and lungs completely harmonize. The regularity suggests an architectural frieze or border. There are exactly five heart beats to every breath. The beat that comes in the outer angle of the curve is very faint for two obvious reasons. Every wave in the curve during sleep has the same form as every other. Even on the occasion when, by descent of the soft palate or for other cause, the subject snored twice (the breaths being shorter and shallower because of the obstruction) the breathing and pulse immediately resumed their harmonic motion in the next breath after snoring stopped. As this subject usually awakes (even after a sound night's sleep) a dream is vanishing. But on this evening there was entire absence of dreams on awaking. Although dreamless sleep may occur more often in the deep sleep of midnight, dreams are certainly, with most persons, the usual accompanyment of the light sleep before awaking.

No hypothesis is to be built on such a narrow basis of fact, but author's experience suggests that this curve will probably not be found in more than one among a thousand experiments in study of the heart and respiration during sleep. The suggestion is here made that in dreamless sleep the activity of the cortex entirely ceases and the reflex functions of the body act in perfect harmony, the ruling function with which all the other bodily functions keep in rhythm being the interchange of CO_2 between the body and the outer world, for the curve shows that there was abundant oxygen in the breathing center.

SUMMARY (With references to experiments). 1. Marey's tambour, rubber pneumographs, etc., are suited only for qualitative work, and must be discarded when accurate results are desired (Figs. 4, 5, 6, 12).

2. Sleep is caused by damping of cerebral (voluntary, conscious) energy and activity by CO_2-excess, and sometimes O-want, which at the same time stimulate the lower automatic breathing centers. The conscious train of ideas is usually terminated by a visible change in respiration (Figs. 8, 13, 14, 15, 17, 21 etc.) which temporarily impedes the circulation (Lewis, Hill and Flack), causing CO_2-excess. (Of course CO_2-excess may not always continue long after sleep comes.)

3. This change may consist of one long pause (Figs. 13, 14), one or more very shallow breaths (Figs. 11, 12, 16, 21) or a number of shallow breaths (Figs. 22, 23).

4. A period of surplus breathing is usually found before the period of deficient breathing (Figs. 16, 17, 23). The surplus period brings on the deficient period, which is apnoic in its nature. Lessened mental activity (Whipple), decrease of sensory stimuli, change to prone position, muscular relaxation tend to apnoea and may aid or take the place of surplus breathing.

5. If the break in respiration stimulates the heart (the larynx not relaxing), the stronger circulation prevents sleep (Figs. 18).

6. If there is merely CO_2-excess, the breaths in sleep or sleepiness will be regular (Figs. 14, 17, 19, 21); if there is also O-want, periodic variations (Figs. 11, 22, 23) ~~in length~~ occur (Douglas and Haldane). In dreamless sleep there is probably no O-want, the breaths are remarkably regular, and pulse and respiration synchronize.

7. The circulation impeded by respiratory change (Hill and Flack, Lewis) is made still slower by vaso-dilation in cortex (Weber,

Hunter, Brodmann, Shepard), slower pulse (Aulo), peripheral dilation (Mosso, Howells), fall of general blood pressure (Hill, Brush and Fayerwether), fall of vascular cerebral pressure (Hammond, Mitchell). A fall of extra-vascular cerebral pressure is not necessary; in fact a slight rise may aid in shifting control to lower centers.

8. Samples of blood for gas analysis if taken from jugular vein with canula just before and just after going to sleep, ought to give some notion of probable amount of CO_2 in extra-vascular cranial spaces; but CO_2 pressure after going to sleep depends more upon blood pressure than upon amount of CO_2. Decapitation experiments with sleeping animals would give only one sample for gas analysis. If result of research is true it will be of hygienic value. In 1899 author put himself to sleep eight times in one hour being reawakened by assistant; has since done so many times. First severe case of insomnia (Miss S—) was relieved in 1903. Practical directions will be given in the paper on Desire.

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Author sends this paper to leading scientists and journals with the hope that corroborating or disproving experiments, also favorable and (especially) unfavorable criticisms, will be sent him to 50 Upper Bedford Place, London (after May, 1910, to 66 Fifth Ave., New York). The paper also appears in the German language in Archiv für die Gesamte Psychologie.

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